Neurons that respond to touch are less picky than expected

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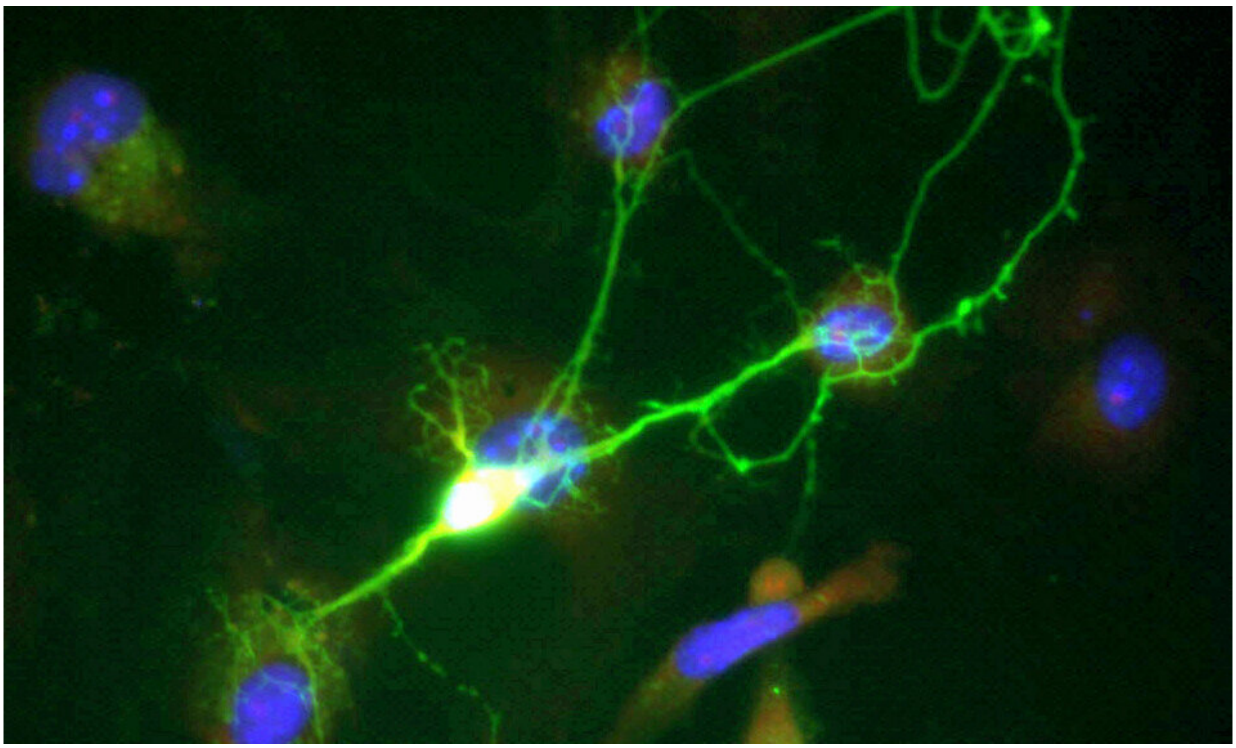

Credit: Public Domain

Researchers used to believe that individual primary touch-sensitive neatly responded to specific types of touch. Now a Northwestern University study finds that touch-sensitive neurons communicate touch in a much messier and jumbled manner.

In the study, the team developed a new technique to stimulate rats' whiskers in three dimensions while simultaneously recording first-stage touch-sensitive neurons in the rats' brains. The researchers discovered that, instead of responding to distinct types of touch, these neurons—which are the first to receive early touch signals—responded to many types of touch and to varying degrees.

The research was published online today in the *Proceedings of the National Academy of Sciences*.

"Many people used to think that each neuron was very precisely tuned for some aspect of the touch stimulus," said Northwestern's Mitra Hartmann, one of the study's senior authors. "We didn't find that at all. Some neurons respond more than others to some features of the stimulus, so there is some degree of tuning. But these neurons respond to many combinations of different forces and torques applied to the whisker."

"When we compared all the recorded neurons, we found that the stimuli they responded to overlapped with each other but not perfectly," added Nicholas Bush, the paper's first author. "It's similar to a painter's palette: We expected to find a handful of 'primary colors," where a neuron could be one of a few different types. But we found the 'palette' had already been mixed. Each neuron was a little different from all the others, but together they covered an entire spectrum."

Hartmann is a professor of biomedical and mechanical engineering at Northwestern's McCormick School of Engineering, where she is a member of the Center for Robotics and Biosystems. A former Ph.D. candidate in Hartmann's laboratory, Bush now is a postdoctoral fellow at the Seattle Children's Research Institute. Sara Solla, a professor of physiology at Northwestern University Feinberg School of Medicine and of physics and astronomy in the Weinberg College of Arts and Sciences, is the other senior author of the study.

Previous studies 'too restricted, simplified'

With just a brush of their whiskers, rats can extract detailed information from their environments, including an object's distance, orientation, shape and texture. This keen ability makes the rat's sensory system ideal for studying the relationship between mechanics (the moving whisker) and sensory input (touch signals sent to the brain). But despite the popularity of using the whisker system to explore the mystery of touch, many long-standing questions remain.

Although large regions of the brain are dedicated to processing touch signals, the number of primary sensory neurons that first acquire tactile information is relatively small and little understood. "There is an 'information bottleneck,'" Bush said. "We wanted to know how the neurons that sense touch are capable of acquiring and representing complex information despite this bottleneck."

While previous studies have explored how neurons respond to a stimulated whisker, those studies were unable to realistically replicate natural touch. In many studies, for example, researchers clipped an anesthetized rat's whisker to about a centimeter in length and then precisely moved the whisker back and forth, micrometers at a time.

"This doesn't at all capture the full flexibility of the whisker," Hartmann said. "It's not how a rat would move in a natural environment. It's a precise stimulation, which gives a precise response, but it's too restricted and simplified."

New comprehensive technique

In Northwestern's study, however, the researchers left the whisker intact and manually stimulated it through a comprehensive range of motions, directions, speeds and forces, up and down the full length of the whisker. Using implanted electrodes to measure the electrical activity of neurons that received the touch signals, the researchers quantified how these neurons responded to a broad range of mechanical signals, much closer to what a real rat would experience in its natural environment. Ultimately, they found that all neurons responded—albeit some more than others—to all different types of stimuli.

"This finding suggests that the sense of touch may be capable of very complex tactile feats because it doesn't throw away or filter much information at that first stage of sensory acquisition before information gets to higher processing centers in the brain," Bush said. "Rather, these early sensory neurons are relaying a high-fidelity—but 'jumbled' or 'messy'—representation. The brain has to be, and clearly is, capable of sorting through the jumble and reconciling it with all the other information available to interpret the sense of touch."

Next, Hartmann and her team plan to combine this new finding with WHISKiT, the first 3D simulation of a rat's whisker system, which was recently developed in her laboratory.

"We can use the WHISKiT model to simulate the mechanical signals that will occur during natural whisking behavior, and then simulate how a population of first-stage touch neurons would respond to those mechanical signals," Hartmann said. "Simulation scenarios will be based on the results we uncovered in this latest study."

More information: Nicholas E. Bush et al, Continuous, multidimensional coding of 3D complex tactile stimuli by primary sensory neurons of the vibrissal system, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2020194118

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